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A PISTON PUMP FOR TAIL PRODUCTION OF OIL

This invention concerns a piston pump for tail production of oil from oil wells having low pressure.

During an initial production period, which may last several years, a typical oil well in the North Sea, for example, will be self-producing. During this production period, the pressure in the oil in the subsurface structure is sufficiently large for the oil to flow up through the well production string by itself. As the oil production period continues, the pressure in the oil-containing structure decreases until the well is not self-producing any more. At this production stage, however, large amounts of oil still remain in the structure, often as much as 80% of the original amount of oil.

According to prior art, mainly three methods of enhanced recovery are used to recover more of the remaining amount of oil in the structure.

One method comprises so-called gas lift, in which gas is injected down via an annulus of the well, after which it

mixes with the oil flowing in from the surrounding oil structure and onwards up through the production string of the well. The admixing of gas lowers the specific gravity and hence the hydrostatic pressure of the emanating fluid column. Thereby, the reduced pressure in the oil structure may still be sufficiently large to overcome the flow friction and the hydrostatic bottom pressure of the fluid column, thus allowing further amounts of oil to be produced from the oil structure during a new time period.

Another method consists in injecting water down into an injection well and into said oil-containing structure, thereby increasing or maintaining the pressure in the oil structure. Further amounts of oils are thus forced out of the structure and produced to the surface via one or more cooperating production wells.

A third method consists in installing a pump downhole in a production string of an oil well. Oil is then pumped up to the surface. Such a pump must be designed for use under extreme conditions. As such, consideration must be given to the fact that the production string is of a relatively small diameter, and that the pump therefore must be formed having dimensions that fit within the production string. Consideration must also be given to the fact that the pump potentially must overcome lifting heights of several thousand meters, and that the pump therefore must be able to operate at very large pressures.

Such prior art pumps usually consist of a large number of axial pumps provided on a long, common shaft, and they have a driving motor provided either below or above the pump itself, insofar as this pump may be 10-20 meters long. The total pump

pressure delivered by such a pump results from a successive pressure build-up in several pressure stages, each pressure stage corresponding to one of said axial pumps along said common shaft. A big problem of these pumps is that they are very sensitive to gas in the oil flow, and they do not operate satisfactorily even when a relatively small gas concentration is present in the outflow. This problem is enhanced when the pressure in said oil structure is reduced in response to oil production, whereby increasingly larger amounts of gas are liberated from the oil, thereby increasing the gas concentration in the oil flow.

Onshore, for example in the USA, it is well known to use piston pumps in relatively shallow wells. Generally, the pump piston downhole in the well is run up and down by means of a wire attached to an eccentric shaft connected to the piston. Each time the piston is moved upwards, such a pump will deliver a pulsating oil flow. This pump solution is acceptable in order to overcome a relatively small oil column pressure at the bottom of a relatively shallow well.

Generally, a piston pump is suitable for providing a large pump pressure in a single pressure stage, which implies that this pressure is provided in the course of one stroke of piston travel within an associated cylinder. Under certain conditions, a piston pump may also handle a relatively large amount of gas in the liquid that it is pumping. For this reason, a piston pump is very much suitable for recovering oil from deep wells having a low pressure in the subsurface structure. Piston-based pumps are disclosed in, for example, publications NO 305667; US 3.625.288; US 4.268.277; US 4.536.137 and GB 2.100.362.

In deep wells, such as those in the North Sea and other offshore regions, a production string oftentimes may be many kilometres long, and the lifting height of the oil column may be 3000-5000 meters. When employing a prior art piston pump to pump out oil in a slugging and pulsating manner from a well, a large proportion of the pump pressure, and hence the pump power, will be used to accelerate the oil column for each pump pulse. Using this pumping principle in a deep well therefore will require an unrealistically large pump pressure and -power to accelerate such a long oil column in a pulsating manner towards the surface. Allowing the oil column overlying the pump to flow having a relatively continuous and even flow out of the well may reduce this disadvantage, thereby avoiding or greatly reducing the pulsating course of acceleration.

The object of the invention is to avoid or reduce said disadvantages of prior art piston pumps. More specifically, the object is to provide a piston pump suitable for mounting downhole in a production string in a deep well; which is of a design capable of delivering a relatively even pump flow of oil to the surface; and which can tolerate relatively large gas amounts in its inflow induction region, the pump simultaneously having very small or no vibration-producing and free mass forces.

The object of the invention is achieved as disclosed in the following description and in the subsequent claims.

The invention concerns a piston pump for pumping out oil from a subsurface structure via an oil well. The piston pump is connected to necessary control- and driving means for controlling and driving the pump, respectively, when placed

in the well. The characterising features of the invention is that the pump has four piston assemblies that, by means of a fixed interlock between two opposite piston assemblies, and by means of a cog wheel interlock between said two piston assemblies and the other two opposite piston assemblies, are provided as two oncoming piston assembly pairs.

With the exception of a short interval when reciprocating, this piston pump design provides the advantageous operation of one piston pump assembly pair always being in a pumping stroke mode, whereas the other pair always is in a concurrent induction stroke mode. The piston pump according to the invention therefore provides the advantage of a virtually continuous and uninterrupted pumping action when operational in a well.

In a preferred embodiment of the invention, the piston pump includes, in sequence: a pump cylinder section; an interlock section; and a drive cylinder section. All of these sections are provided with a centrally provided oil outlet channel through which recovered oil may flow onwards and out of the well. Internally, the pump cylinder section, the interlock section and the drive cylinder section are provided with four axial cylinder assemblies distributed peripherally about the oil outlet channel. Each cylinder assembly comprises: a pump cylinder in the pump cylinder section; an inwardly open movement region in the interlock section; and a drive cylinder in the drive cylinder section. Internally, each cylinder assembly is provided with an axially movable piston assembly, each piston assembly comprising: a pump piston in the pump cylinder; a piston rod in the inwardly open movement region; and a drive piston in the drive cylinder. Two diametrically opposite piston rods are mechanically connected

by means of a linkage that is provided between them. Each of said two mechanically connected piston rods is movably connected to one of the other two piston rods via a cog wheel provided therebetween, both of said cog wheels being supported in the interlock section. Each piston rod is also provided with a pitch rack portion facing towards said cog wheel and having a length corresponding to at least the stroke length of said pistons.

Said four axial cylinder assemblies distributed peripherally about the oil outlet channel may also be distributed at an equal angle distance between each another. Moreover, said inwardly open movement region in the interlock section may be comprised of a partially cylinder-shaped groove (as viewed in cross section). Furthermore, said mechanical linkage in the interlock section may be comprised of a tie-plate.

An example of an embodiment of the present piston pump will be described hereinafter whilst referring to the accompanying figures, in which:

Figure 1 shows a lower portion of a production string of a well, within which portion a piston pump according to the invention is provided;

Figure 2 shows a schematic, radial cross section through the piston pump, also indicating a section line III-III through the pump;

Figure 3 shows an eccentric axial section through the piston pump as viewed along section line III-III of figure 2, figure 3 also showing a section line VI-VI through the pump;

Figure 4 shows another schematic, radial cross section through the piston pump, also indicating a section line IV-IV through the pump;

Figure 5 shows a central axial section through the piston pump as viewed along section line IV-IV of figure 4, figure 5 also showing a section line VII-VII through the pump;

Figure 6 shows an enlarged and further detailed radial cross section through the piston pump as viewed along section line VI-VI of figure 3; and

Figure 7 shows an enlarged and further detailed radial cross section through the piston pump as viewed along section line VII-VII of figure 5.

Figure 1 shows a piston pump 2 according to the invention. Viewed from below and up, the pump 2 comprises: a suction mouth piece 4; a pump valve section 6; a pump cylinder section 8; an interlock section 10; a drive cylinder section 12; a control valve section 14; and a hydraulic drive unit 16 on top. A pump (not shown) in the drive unit 16 pumps hydraulic fluid in a loop between a bistable 3-5 port valve (not shown) in the control valve section 14, and the drive unit 16. In the control valve section 14, the hydraulic fluid is guided further through suitable hydraulic fluid channels (not shown) onwards to respective drive cylinders 26a, 26b, 26c and 26d in the drive cylinder section 12. Supply of driving power and control signals to the drive unit 16, as well as conveyance and control of the hydraulic fluid flow paths within the pump 2, constitutes prior art and will not be described any further hereinafter.

The pump cylinder section 8, the interlock section 10 and the drive cylinder section 12 all are provided with a centrally provided oil outlet channel 18, which is best shown in figures 6 and 7. Oil, which is sucked in through the mouth piece 4 by means of the piston pump 2, is guided into the oil outlet channel 18 by means of prior art control valves arranged in the pump valve section 6. The oil outlet channel 18 also continues through the control valve section 14 and the hydraulic drive unit 16 and exits in the well's production string 20. Thus, recovered oil may be pumped onwards to the surface.

Four cylinder assemblies A, B, C and D are provided radially outside of the oil outlet channel 18 and surround the channel 18. As shown for example in figures 3 and 5, internally the pump cylinder section 8 is provided with four axial pump cylinders 22a, 22b, 22c and 22d distributed peripherally at an equal angle distance between each another. Internally the material of the interlock section 10 is provided with four axial and partially cylinder-shaped grooves 24a, 24b, 24c and 24d distributed peripherally at an equal angle distance between each another. Analogously, internally the drive cylinder section 12 is provided with said four axial drive cylinders 26a, 26b, 26c, 26d also distributed peripherally at an equal angle distance between each another. Each pump cylinder 22a, 22b, 22c, 22d is aligned with a corresponding, partially cylinder-shaped groove 24a, 24b, 24c, 24d, and with a corresponding drive cylinder 26a, 26b, 26c, 26d.

Internally in each cylinder assembly A, B, C, D, an axially movable piston assembly a, b, c and d is provided, comprising, in sequence: a pump piston in one end; a piston rod; and a drive piston in the other end, cf. figures 3 and

5. Thus, four piston assemblies a, b, c, d are provided, one of which in each cylinder assembly A, B, C, D. The piston assemblies a, b, c, d comprise: four respective pump pistons 28a, 28b, 28c and 28d; four respective piston rods 30a, 30b, 30c and 30d; and four respective drive pistons 32a, 32b, 32c and 32d. The side of the pump cylinders 22a, 22b, 22c, 22d and the drive cylinder 26a, 26b, 26c, 26d arranged closest to the interlock section 10, is provided with a shoulder 34 against which the rear side of each piston can stop when operational and reciprocating back and forth in its cylinder.

Two diametrically opposite piston rods 30b and 30d are mechanically connected by means of a linkage or a tie-plate 36 provided between them. Thereby, piston assembly b will move uniformly together with piston assembly d throughout their reciprocating axial movements. The tie-plate 36 is best shown in figures 5 and 7. Two other diametrically opposite piston rods 30a and 30c are not connected via such a mechanical linkage.

However, piston rod 30a and piston rod 30d, and piston rod 30c and piston rod 30b, respectively, are movably connected with each other via a cog wheel 38 and cog wheel 38′, respectively, provided between them, both of said cog wheels 38, 38′ being supported in the interlock section 10. In this connection, each piston rod 30a, 30b, 30c, 30d is provided with a pitch rack portion 40 facing in towards the respective cog wheel 38, 38′ in order to engage and cooperate with the cog wheel 38, 38′. The pitch rack portion 40 has a length corresponding to at least the stroke length of each piston. This tooth interaction is best shown in figures 3 and 6. When the two mechanically connected piston assemblies b and d move uniformly together in one axial direction, the cog wheels 38,

38' will ensure that a coordinated and uniform movement of the other two piston assemblies a and c in the opposite axial direction is provided. Thereby, two drive pistons as well as two pump pistons will always be active simultaneously during operation of the piston pump 2. Moreover, this is a direct result of the four piston assemblies a, b, c, d of the pump 2 being provided as two oncoming piston assembly pairs b, d and a, c. This piston pump design also results in a complete balancing of the mass forces in the pump 2. Simultaneously, the emanating oil flow becomes relatively constant and even, even when a pressure surge arises when the pistons change their direction of movement due to their axial reciprocation.

Said pressure surge is used to switch said bistable 3-5 port valve in order to supply pump-driving hydraulic fluid alternately to a first drive cylinder pair 26b, 26d and a second drive cylinder pair 26a, 26c. In relation to this, the opening of said hydraulic fluid channel in each drive cylinder 26a, 26b, 26c, 26d may be provided at some distance below the top of the cylinder. When a drive piston 32a, 32b, 32c, 32d moves towards the cylinder top in its respective drive cylinder 26a, 26b, 26c, 26d, a hydraulic fluid cushion thus will be present between said opening for hydraulic fluid, and the cylinder top. As such, each drive piston 32a, 32b, 32c, 32d will stop against an impact-absorbing hydraulic fluid cushion instead of stopping mechanically against a drive cylinder top. Such a hydraulic fluid cushion provides a quieter and less straining working action to the piston pump 2.